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STATISTICAL ANALYSIS OF THE EFFECT OF POT SOAK-TIME ON THE CATCH OF KING CRAB (*Paralithodes camtschatica*) AND TANNER CRAB (*Chionoecetes bairdi*) IN CHINIAK GULLY NEAR KODIAK ISLAND, ALASKA

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ABSTRACT

A study was conducted in July 1984 by the Alaska Department of Fish and Game in Chiniak Gully off Kodiak Island, Alaska, to determine the effect of crab pot (trap) soak-time on the number of crab caught. Pots soaking 12, 24, and 48 hours were incorporated into an experimental design that either controlled or partitioned out the sources of variability not attributable to duration of soak. The responses to pot soak-time by king crab (*Paralithodes camtschatica*) and Tanner crab (*Chionoecetes bairdi*) were statistically significant (P < 0.06) and showed different patterns for the two species. The number of female Tanner crab declined with increased soak-time. Male Tanner crab increased in numbers with an increased soak-time, but less markedly than male and female king crab. The average number of king crab caught in pots soaked 48 hours was more than twice the average number caught in pots soaked 24 hours. The average number of king crab caught in pots soaked 12 hours was less than half the number caught in 24 hours. When compared to the currently used method of standardization of numbers of crab counts to reflect a 24-hour pot soak, the 12-hour, and 48-hour current standardization provides over- and under-estimates respectively for king crab and the converse for Tanner crab. The multivariate correlation was 91% between the numbers of the crab species by sex groups and the independent variables indicating that the independent variables did account for important variation in the number of crabs occurring simultaneously in the pots.

KEY WORDS: king crab, Tanner crab, trap soak-time, analysis of covariance, canonical correlation, unbalanced incomplete block design.

INTRODUCTION

The pot (trap) survey method for estimating king crab *(Paralithodes camtschatica)* and Tanner crab (*Chionoecetes bairdi*) populations utilized by the Alaska Department of Fish and Game incorporates an adjustment to number of crab caught based on the duration of the soak (Alaska Department of Fish and Game 1984). Previous work to quantify the effect of soak-time has utilized information from fishermen's logbooks to adjust the catch of king crab (Rothschild et al. 1970). Catch records from fishermen's logbooks are not good substitutes for experimental fishing. Logbook records do not meet experimental assumptions on randomization of treatments over space and time, and the quality of the recorded data can be wanting (Miller 1983). The logbook program provides a minimum recordable time of 1 day, and "one day" means overnight and can range from 12 to 36 hours duration. The adjustment of the catch of a pot that is soaked less than 1 day results in bias problems because the desired prediction is outside the range of the data. Prediction errors are especially magnified if the relationship between catch and soak-time is non-linear. In July of 1984, the Alaska Department of Fish and Game undertook a special study to address the accuracy of the current adjustment formula and to better define the relationship between soak-time and number of crab caught.

METHODS

Study Site

An experimental design was conceived to take into account the sources of variability that were thought to be the major components that would occur in a pot soak-time study. The first consideration was that of a homogeneous distribution of king and Tanner crab in the area to be sampled. To locate an area were the crab were evenly dispersed, several areas were sampled with pots by a charter vessel prior to July 20th. A study area between latitudes 57° 31.77' and 57 °33.47' and between longitudes 151 °44.48' and 151 ° 47.28' was chosen (Figure 1). The study area (Figure 2) consisted of two adjacent blocks, each with 16 sample locations in a four by four grid in essentially a flat bottom area of 146 to 155 m (80 to 85 fm). The pots were evenly spaced at an 0.8 km (0.5 mile) distance; a separation considered sufficient to stop competition or interaction among pots, and keep the observations independent. Additional data was also collected at the south-west end of the island in a similar manner (Appendix A).

Sampling Procedure

Commercial size king crab pots measuring 2.1 m x 2.1 m x 76 cm (7 ft x 7 ft x 30 in) were used in the study. Each pot weighing approximately 295 kg (650 lb), was lined with 8.9 cm (3.5 in) stretch mesh and was fitted with two tunnel eyes with vertical and horizontal measurements of 20 cm x 91 cm (8 in x 36 in) respectively. Each pot was baited with frozen herring in each of two 1.0 liter (1 qt) plastic jugs suspended from the center of the pot. In the sampled area each four by four grid constituted a block and contained four 12-hour, eight 24-hour, and four 48-hour pots. For each

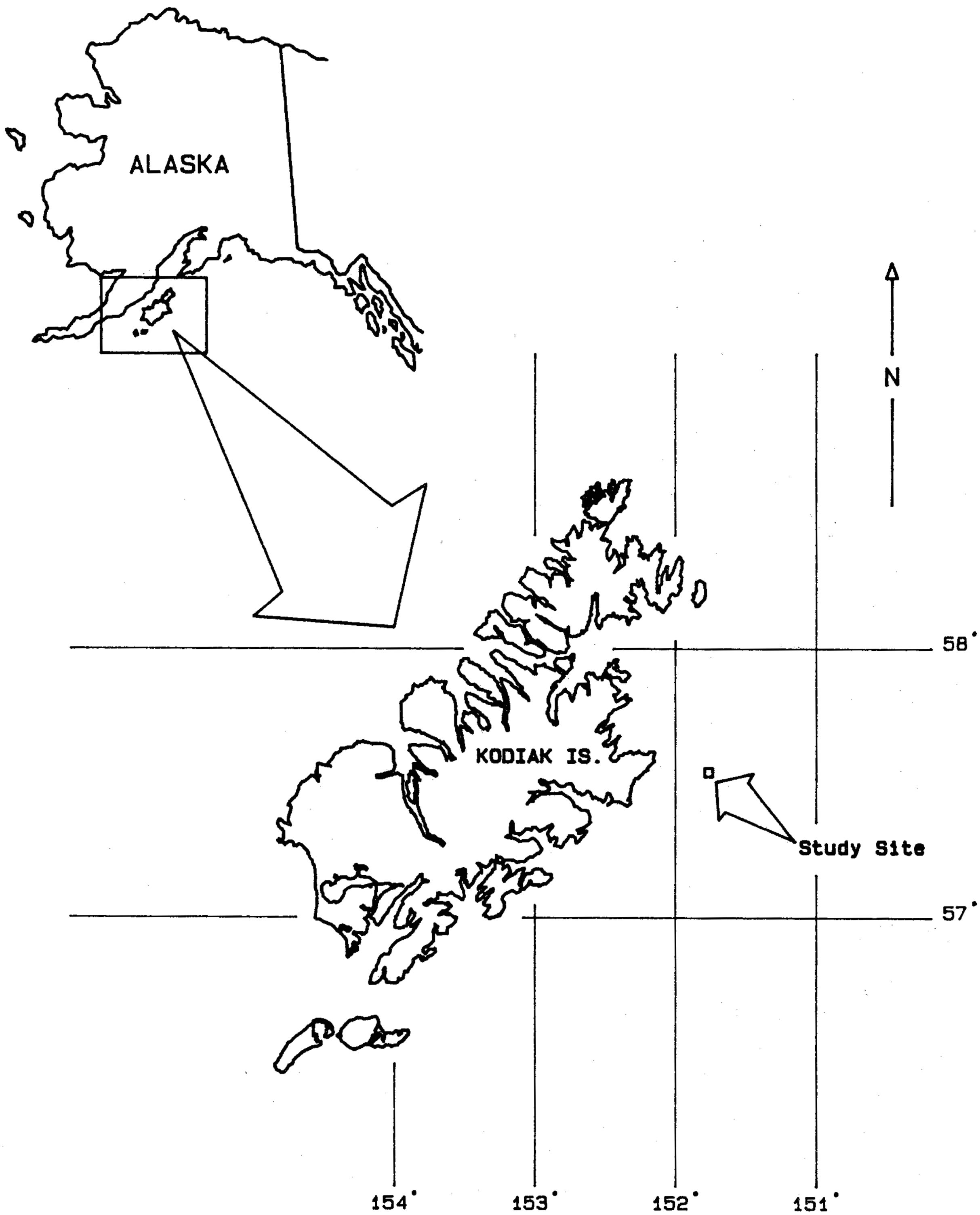

Figure 1. Study site area off Kodiak Island, Alaska.

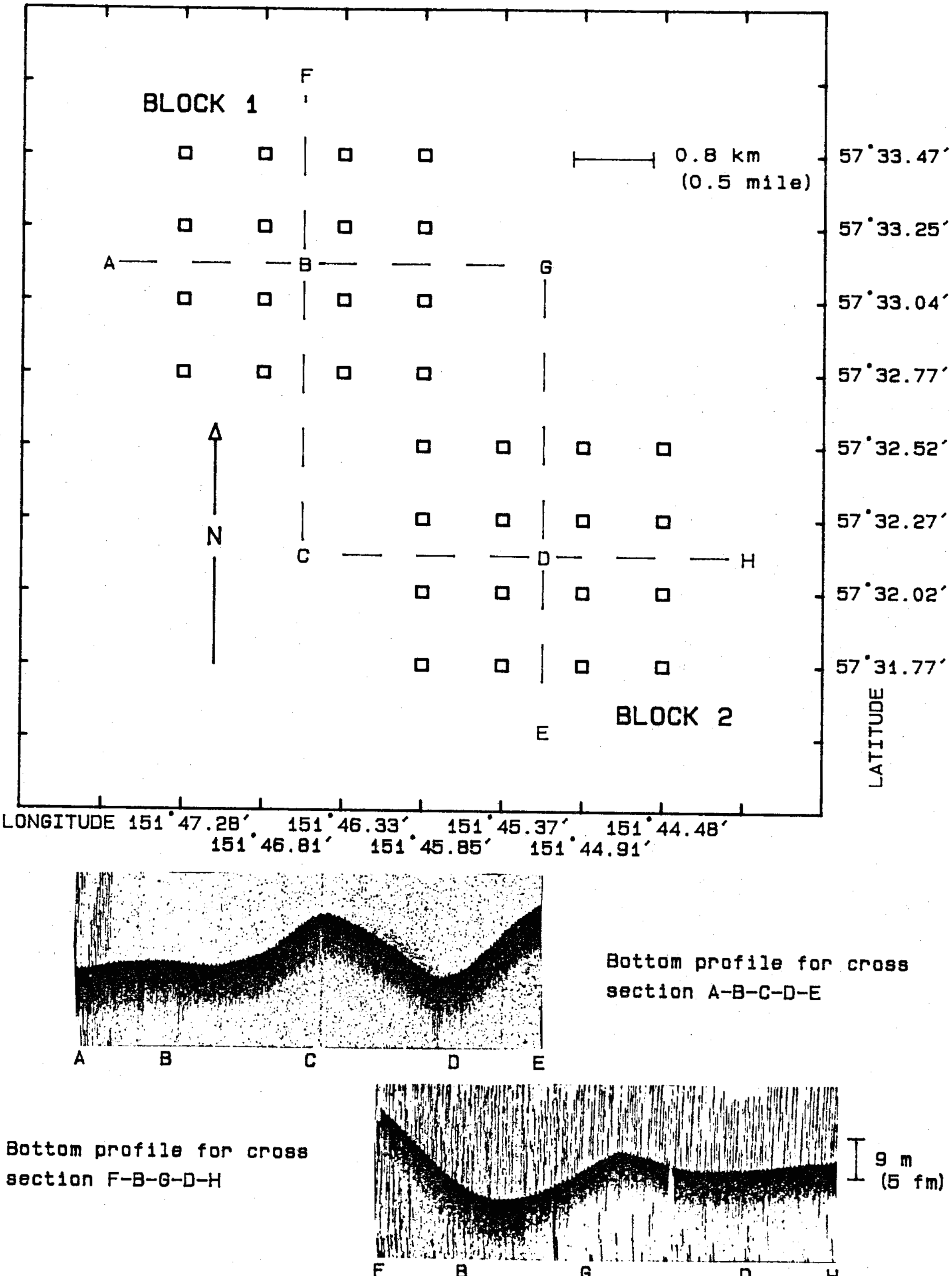

Figure 2. Sample station locations and bottom profile of study site.

block, the pots were randomly assigned one of the three soak-times and location within the block. The logistics of handling gear did not allow for all pots to be set or lifted at an identical time of day. Therefore, a 15 minute interval was allowed between the lifting of each pot, with the starting time for Block 1 at 0800 hours and for Block 2 at 1600 hours. Each 12-hour pot was set and lifted four times, each 24-hour pot was set and lifted twice, and each 48-hour pot was set and lifted once. For each pot lifted, the observed variables were the number of each crab species by sex, the number of Pacific cod (*Gadus macrocephalus*), the number of Pacific halibut (*Hippoglossus stenolepis*), the actual time of soak, the time set, the time lifted, the depth in fathoms at the location of the set, the sample location, and the basic morphometric measurements of the crab. The morphometric characteristics were not considered in this analysis.

Statistical Analysis

Each 0.8 km (0.5 mile) square of the sampled area constitutes an experimental unit to which the treatments in the experimental design were randomly applied. The treatment was soak-time with treatment levels chosen at 12, 24, or 48 hours. Since the study objective was the effect of soak-time on catch, the design precludes the analysis of the effect of halibut or cod on the catch of crab. Although the major treatment or factor in this study is soak-time, two other factors that can be considered are the time of set (AM versus PM) and the day in the study (first half and second half of the study). In this study, the two additional factors and blocking were utilized to partition sources of variability due to within-day, between-day, and blocking (area) so that the effects of soak-time could be isolated. Usually the factors and treatment levels of each factor are defined prior to conducting an experiment and are assigned randomly to provide all combinations that can be formed from different factors; a complete factorial design. However, the within-day and between-day factors were constrained and could not be applied randomly and at all levels of the soak-time factor. For example, a pot with a treatment level of 12 hours and set in the AM did not coexist with a pot with the same treatment level set in the PM.

A goal of experimental design is to keep things simple. Depth, pot size, type of mesh, number of bait jars, and type of bait were held constant. The bait was not replenished during the study so that 12-hour and 24-hour pots had approximately the same condition of bait as the 48-hour pots. In addition to the three factors, the analysis included the number of halibut, the number of cod, and a variable that measured within-day deviations in tide height at the time the pot was lifted. It was thought that halibut, cod, and the tides would be independent sources of variability in the catch of crab. The time the pot was lifted, lift-time, is defined to be the time when the pot was retrieved. The recorded time was the time at which the first shot (length of line) passed through the hydraulic block and was thought to best represent the time at which the pot left the bottom. Each variable was adjusted to it's mean (Neter and Wasserman 1974) to reflect deviation from an average zero effect. The lift-time variable prior to adjustment to it's mean was transformed to reflect deviations from daily afternoon time of low tide (Table 1). Inclusion of continuous independent variables results in an analysis of covariance. The method allows for the elimination of the effects of these independent variables from the estimates of the treatment effects (Cochran and Cox 1957).

The extra sums-of-squares method along with the generalized F-test was used to test the significance of factor and covariate effects (Neter and Wasserman 1974; Snedecor and Cochran 1967). The experimental design is an incomplete factorial randomized block design (Cox 1958). With the treatment levels at unequal sample size, the design is also unbalanced (Searle 1971). Specification and discussion of the experimental design considerations and the underlying assumptions of the model are covered in Appendix B and by Searle (1971) and Cochran and Cox (1957).

The initial full model is the model that contains all possible variables of interest and takes the abbreviated form

$$y = b_0 + \sum_{i=1}^{5} b_i x_i + \sum_{j=1}^{3} b_{j+5} z_j + \varepsilon$$

where:

$$x_1 = \begin{cases} 1 & \text{if observation from block 2} \\ -1 & \text{if observation from block 1} \end{cases}$$

$$x_2 = \begin{cases} 1 & \text{if observation from a PM pot set} \\ -1 & \text{if observation from a AM pot set} \end{cases}$$

$$x_3 = \begin{cases} 1 & \text{if observation from second half of study} \\ -1 & \text{if observation from first half of study} \end{cases}$$

$$x_4 = \begin{cases} 1 & \text{if observation from 12-hour pot} \\ -1 & \text{if observation from 24-hour pot} \\ 0 & \text{otherwise} \end{cases}$$

and

$$x_5 = \begin{cases} 1 & \text{if observation from 48-hour pot} \\ -1 & \text{if observation from 24-hour pot} \\ 0 & \text{otherwise} \end{cases}$$

The error terms (ε) are assumed to be normally distributed with mean zero and variance σ^2. The z_j are the covariates and are associated with lift-time, number of halibut, and number of cod per pot lift. Each is adjusted for it's respective mean to make the regression parameters easier to interpret. The description and interpretation of the regression parameters are presented in the results. Seven different dependent variables, y , are used in this study. The first is the total number of crab as the dependent variable, others were total king crab, total Tanner crab, male king crab, female king crab, male Tanner crab, and female Tanner crab. The

Table 1. Time of high and low tides for the Kodiak, Alaska, district for the period 20 July to 22 July 1984.

Date	High Tide		Low Tide	
20	0706	2000	0123	1315
21	0811	2047	0226	1355
22	0935	2138	0335	1442

Source: NOAA 1983.

analysis of the data (Appendix C) was conducted utilizing MINITAB (Ryan et al. 1981) and BMDP (Dixon 1981) statistical software.

RESULTS AND DISCUSSION

The number of male and female king crab and male and female Tanner crab caught represent the four sex/species of observed crab. Since the four sex/species combinations of number of crab measured is based upon within-pot co-occurrence, the relationship between the simultaneous occurrences of each species by sex and the effect of the independent variables is important. One way to measure the relationship is to look at the correlation between the number of crab by species/sex and the set of independent variables. Canonical correlation (Morrison 1976; Muller 1982) is a measure of the extent of the linear relationships between two sets of variables. The proportion of the variance from the linear combination of the four counts of male and female Tanner and king crabs in each pot that is explained by the linear combination of the independent variables is 91%. The observed number and combination of crab in the pot is highly related to the independent variables, indicating that the independent variables (soak-time, area, AM versus PM set, first half versus second half of the study, lift-time, number of halibut, and number of cod) do account for important variation in the dependent variables. The high correlation reinforces the concept of interrelationships between king and Tanner crabs, and illustrates the need for a multivariate view in attempting to understand the natural processes. However, for the purpose of providing ease of interpretation for this study, the univariate approach will continue to be the analysis framework.

For the seven separate analyses of the dependent variable y , the number of crab in the pot, the initial full models are provided in Table 2. Initial graphical interpretation of the existence of first-order and higher-order interaction effects indicated that the assumption of no interactions was appropriate. The independent variables, both treatment type and covariate type, were tested sequentially for significance to each model at the 0.1 α-level. The resultant models are provided in Table 3 which also specifies the P-values to indicate the α -level at which rejection of no effect would have occurred.

Interpretation

Interpretation of the regression coefficients in the analysis of covariance has been simplified by the choice of the values for the indicator variables. For each of the final models (Table 3), the b_0 value is the estimate of the overall mean number of crabs for a 24-hour soak when all effects are at a mean level. The b_4 and the b_5 values are deviations from the overall mean as a result of the treatment effects of 12-hour and 48-hour soak-times, respectively. The parameters associated with the effect of blocking, within-day, and between-day can be viewed as extraneous sources of variability that hide the true effect of soak-time. There are several reasons for not discussing the additional factors. The actual

Table 2. Analysis of covariance regression coefficients for the initial full models.

Name:	Overall Mean	Block	AM/PM	Half	12-hr	48-hr	Lift Time	Halibut	Pacific Cod
Symbol:	b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
Dependent Variable									
Total crab	39.51	2.08	2.72	-8.80	-17.95	21.74	-0.70	-9.07	-1.08
Total king	22.27	-0.98	0.22	-5.52	-16.45	23.55	0.20	-4.73	-0.89
Male king	0.63	-0.02	0.10	-0.20	-0.59	0.85	0.03	-0.14	-0.06
Female king	21.64	-0.96	0.13	-5.32	-15.86	22.70	0.17	-4.59	-0.82
Total Tanner	17.24	3.06	2.50	-3.27	-1.51	-1.81	-0.90	-4.34	-0.19
Male Tanner	10.01	-0.80	0.82	-1.82	-2.01	0.90	-0.44	-0.88	-0.11
Female Tanner	7.23	3.85	1.67	-1.45	0.51	-2.71	-0.47	-3.46	-0.08

Table 3. Analysis of covariance regression coefficients for the final reduced models.

<table>
<tr><td>Name:</td><td>Overall Mean</td><td>Block</td><td>AM/PM</td><td>Half</td><td>12-hr</td><td>48-hr</td><td>Lift Time</td><td>Halibut</td><td>Pacific Cod</td></tr>
<tr><td>Symbol:</td><td>b_0</td><td>b_1</td><td>b_2</td><td>b_3</td><td>b_4</td><td>b_5</td><td>b_6</td><td>b_7</td><td>b_8</td></tr>
<tr><td>P-value:</td><td></td><td>(P=)</td><td>(P=)</td><td>(P=)</td><td>(P=)</td><td>(P=)</td><td>(P=)</td><td>(P=)</td><td>(P=)</td></tr>
<tr><td>Dependent Variable</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total crab</td><td>39.77</td><td>4.53</td><td></td><td>-8.32</td><td>-18.59</td><td>22.52</td><td>-1.16</td><td>-8.56</td><td></td></tr>
<tr><td></td><td></td><td>(0.06)</td><td>(0.16)</td><td>(<0.01)</td><td colspan="2">(<0.01)</td><td>(0.04)</td><td>(<0.01)</td><td>(0.34)</td></tr>
<tr><td>Total king</td><td>22.56</td><td></td><td></td><td>-5.07</td><td>-17.08</td><td>24.42</td><td></td><td>-4.60</td><td></td></tr>
<tr><td></td><td></td><td>(0.65)</td><td>(0.84)</td><td>(<0.01)</td><td colspan="2">(<0.01)</td><td>(0.89)</td><td>(<0.01)</td><td>(0.29)</td></tr>
<tr><td>Male king</td><td>0.64</td><td></td><td></td><td>-0.17</td><td>-0.60</td><td>0.86</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>(0.91)</td><td>(0.13)</td><td>(0.01)</td><td colspan="2">(<0.01)</td><td>(0.30)</td><td>(0.105)</td><td>(0.13)</td></tr>
<tr><td>Female king</td><td>21.91</td><td></td><td></td><td>-4.90</td><td>-16.46</td><td>23.53</td><td></td><td>-4.50</td><td></td></tr>
<tr><td></td><td></td><td>(0.74)</td><td>(0.72)</td><td>(<0.01)</td><td colspan="2">(<0.01)</td><td>(0.93)</td><td>(<0.01)</td><td>(0.33)</td></tr>
<tr><td>Total Tanner</td><td>17.31</td><td>3.09</td><td>2.62</td><td>-3.17</td><td>-1.65</td><td>-1.62</td><td>-0.94</td><td>-4.31</td><td></td></tr>
<tr><td></td><td></td><td>(0.03)</td><td>(0.06)</td><td>(<0.01)</td><td colspan="2">(0.06)</td><td>(<0.01)</td><td>(<0.01)</td><td>(0.77)</td></tr>
<tr><td>Male Tanner</td><td>9.94</td><td></td><td></td><td>-1.79</td><td>-1.90</td><td>0.69</td><td>-0.55</td><td></td><td></td></tr>
<tr><td></td><td></td><td>(0.29)</td><td>(0.45)</td><td>(<0.01)</td><td colspan="2">(<0.01)</td><td>(<0.01)</td><td>(0.20)</td><td>(0.74)</td></tr>
<tr><td>Female Tanner</td><td>7.21</td><td>5.02</td><td></td><td>-1.46</td><td>0.53</td><td>-2.80</td><td>-0.62</td><td>-3.27</td><td></td></tr>
<tr><td></td><td></td><td>(<0.01)</td><td>(0.11)</td><td>(0.09)</td><td colspan="2">(0.03)</td><td>(<0.01)</td><td>(<0.01)</td><td>(0.86)</td></tr>
</table>

blocking and sequence of pot lifts due to the constraints of time caused a situation in which the blocking effect is confounded (Cox 1958) with AM versus PM pot set. There are no 24- or 48-hour pots set in the PM in Block 1, or in the AM for Block 2. The first day versus second day effect is actually the first half and second half of each block and creates a time overlap situation between blocks. However, the factors do provide a means of partitioning the sources of variability occurring during the study. In addition to the main effects of the variables, at the basic level there are interactions provided by the blocking, within-day, and between-day effects, due to their definitions and, as a result, in all likelihood provide sufficient coverage through confounding of the possible sources of variability extraneous to the soak-time variability. The standard errors attributable to the soak-time estimated effects for each of the models illustrates the magnitude of variance associated with each estimate (Table 4). The standard errors are of each treatment level additive effect (the regression coefficients).

For all models, there is no significant effect of Pacific cod. However, the reduced models illustrate the effect of halibut in the pot on crab catch. All models that indicate a significant halibut effect show a reduction (negative regression coefficient) in number of crab as the number of halibut increases (Table 3). The two models that do not, are the models for male king and male Tanner crab. Since the male and female king crab show similar patterns in the 12-hour and 48-hour percentage deviations from the 24-hour counts (Table 5), the possible explanation for lack of halibut effect on the male king crab counts is the overall low counts that were observed. In addition, the P-value was close to the rejection α-level (Table 3). However, the additional data collected from the south-west end of Kodiak Island (Appendix A), where a greater number of male king crab were caught, show the same lack of halibut effect (Table 6).

The analysis of male king crab caught in the south-west end indicates additional effects due to area, AM versus PM, and time of pot lift. Whether the data from two different areas are comparable is not within the experimental design framework of this analysis and are utilized solely to quantify any major deviations in pattern for male king crab.

The average number of Tanner crab for both sexes combined show a decrease in counts as the pot is soaked longer than 24 hours. Since male Tanner crab show an increase over time, the decrease effect is attributable to female Tanner crab that after 12 hours show a continual decline (Table 4). Previous work has shown escapement of king crabs from pots similar to those utilized in this study and it is speculated that the greater activity of Tanner crab and the smaller size allows for a higher rate of escapement (High and Worlund 1979). The fact that female Tanner crab are smaller than male Tanner crab may contribute to the reduction in numbers for the longer soaked pots. Other causes that should not be ruled out are the possibility of predation by halibut or avoidance of halibut by Tanner crab.

Table 4. Estimated number of crab at each soak-time level and standard errors of each treatment level effect.

Dependent Variable	Estimated number of crab (SE) 12-hour		24-hour		48-hour	
All crab	21.18	(7.35)	39.77	(4.83)	62.28	(14.82)
Total king	5.48	(3.77)	22.56	(2.48)	46.98	(7.56)
Male king	0.03	(0.009)	0.64	(0.006)	1.50	(0.019)
Female king	5.45	(3.77)	21.91	(2.48)	45.44	(7.56)
Total Tanner	15.66	(2.40)	17.31	(1.58)	15.69	(4.84)
Male Tanner	8.04	(0.62)	9.94	(0.41)	10.63	(1.24)
Female Tanner	7.74	(1.47)	7.21	(0.97)	4.41	(2.97)

Table 5. Soak-time effect on observed crab counts as a percentage deviation from the number of crab caught in 24-hour pots.

Dependent Variable	12-hour	48-hour
Total king	-75.7	108.3
Male king	-95.1	136.1
Female king	-75.1	107.4
Total Tanner	-9.5	-9.3
Male Tanner	-19.1	7.0
Female Tanner	7.3	-38.8
Male king (additional data)	-80.1	105.8

Table 6. Analysis of covariance regression coefficients for the final reduced male king crab model from the additional data.

	Overall						Lift		Pacific
Name:	Mean	Block	AM/PM	Half	12-hr	48-hr	Time	Halibut	Cod
Symbol:	b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
P-value:		(P=)	(P=)	(P=)	(P=)	(P=)	(P=)	(P=)	(P=)
Dependent Variable									
Male king	3.67	0.66	1.24	-0.58	-2.94	3.88	0.13		
		(0.07)	(<0.01)	(0.04)	(<0.01)		(<0.04)	(0.44)	(0.89)
Male king (Chiniak Gully)	0.64			-0.17	-0.60	0.86			
		(0.91)	(0.13)	(0.01)	(<0.01)		(0.30)	(0.105)	(0.13)

Adjustment of Catch

The possible soak-time adjustment/standardizations for number of crab caught in pots soaked at times different from 24 hours that could be derived from this study differ from the current adjustment factors (Table 7). The difference between the two sets of adjustments indicates a particular pattern for pots soaked 12 and 48 hours. Compared to the results of this study, the current approach over-estimates both sexes of king crab for 12-hour soaks and under-estimates both sexes of Tanner crab for the same period of soak (Table 8). The opposite holds for soak-times of 48 hours. The comparison is made by first setting the catch equal at 24 hours for both approaches, followed by comparing the differences for the two approaches for 12-hour and 48-hour estimates. The standardization is reversed for the common use of the soak adjustments in Table 7, in that the catch is adjusted <u>to</u> a 24-hour catch, not <u>from</u> a 24-hour catch. The additional information from the south-west end reinforces the concept of over- and under-estimating male king crab counts (Table 8) for 12-hour and 48-hour soak duration respectively, even though the data was obtained from another area.

As with any comparison of point estimates, it must be emphasized that only two different soak-times are compared to the 24-hour catch, and not a range of data points between 12 and 48 hours. The final models are influenced by area, crab densities, depth, tide, and time of day. The potential user is cautioned that the models may not be appropriate for values of the variables outside those observed in this study. Even though the additional information reinforces over- and under-estimation patterns, the values are dissimilar perhaps due to area, time of sampling, and density levels.

CONCLUSIONS

The experimental design of this study partitioned some of the sources of variability that obscure the effect of soak-time of crab pots. There was a canonical correlation of 91% between the numbers of crab occurring simultaneously in the pot and the independent variables. There is difficulty in interpreting a single crab species/sex response to soak-time when an interrelationship between the various crab species/sex combinations in each pot and the independent variables does exists. However, statistically significant patterns were found that illustrate the basic effect of soak-time on the number caught of each crab species/sex.

One conclusion is obvious from the analyses. The different crab species/sex occurring in a pot soaked different lengths of time respond differently. Using the same adjustment formula for all species and sex of crab causes biased estimates. In addition, even if the response was similar, the interrelationship between the crab in a single pot affects resultant species/sex composition in the pot. The general conclusions that can be drawn are that halibut negatively affect the numbers of crab in the pot; and female Tanner crab avoid or escape from the pot after 12 hours. The number of male king crab increase with a longer soak. Female king crab and male king crab show a greater number in a 48-hour pot than if two 24-hour pots were soaked. Male Tanner crab show the opposite response.

Table 7. Currently used adjustment to individual pot catch based on soak-time.

	Days soaked										
	0	1	2	3	4	5	6	7	8	9	> 9
Soak factor (divisor)	0.0	1.0	1.5	2.0	2.33	2.67	3.0	3.25	3.5	3.75	4.0

(linear interpolation between days)

Source: Colgate and Hicks 1981.

Table 8. Percentage difference between current adjustment approach and study results for estimated number of crab in a pot at 12 and 48 hours based on a 24-hour catch of 100 crab.

	12 hours			48 hours		
	Estimated Number of crabs			Estimated Number of crabs		
Species/sex	(1) Study Results	Current (0.5%)	% of (1)	(2) Study Results	Current (1.5%)	% of (2)
Male king	4.9	50.0	920	236.1	150.0	-36
Female king	24.9	50.0	101	207.4	150.0	-28
Male Tanner	80.9	50.0	-38	107.0	150.0	40
Female Tanner	107.3	50.0	-53	61.2	150.0	145
Male king (additional data)	19.9	50.0	152	205.8	150.0	-27

The current adjustment approach over-estimates both sexes of king crab for a 12-hour soak and under-estimates both sexes of Tanner crab. For the 48-hour soak, the opposite results. The assumption that the effect of soak-time, as quantified by this study, may also apply to areas other than Chiniak Gully, in different times of the year, and for different crab density levels is an assumption that needs to be thoroughly addressed prior to application under dissimilar conditions.

RECOMMENDATIONS

1) To quantitatively evaluate the accuracy of the currently utilized adjustment/standardization factors, more than three time intervals are needed. The 12-hour and 48-hour deviations from a 24-hour soak might not be representative of deviations for other lengths of soak, times of year, areas or crab densities. Therefore, extrapolation or interpolation of the results of this study carries some element of risk.

2) It is recommended that further research should be considered to provide observations at soak-times between 12- and 24-hours, other crab densities, other areas, and at other times of the year. In all likelihood, as a result of varying levels of crab densities, a family of adjustment curves might exist. There may be a near-optimal soak-time. Also, a multivariate design and analysis is needed to determine how the presence of one group of crab affects the presence of the other in survey pots. Further analysis of interaction effects should also be looked at. Extensive planning will be necessary if the aforementioned objectives are to be met.

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Appendix A. Additional male king crab data collected during the period of 5-7 August 1984.

Appendix Table A-1. Number of male king crab, design matrix, and covariates.

The timing of pot lifts differs from the Chiniak Gully data in that the starting time for Block 1 was 0815 hours. The columns correspond to the following variables:

1) Number of male king crab
2 - 6) x_1 through x_5
7 - 9) z_1 through z_3

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	-1	-1	-1	1	0	7.996	0.444	1.347
0	-1	-1	-1	1	0	8.216	1.444	9.347
0	-1	-1	-1	1	0	8.486	-0.556	9.347
0	-1	-1	-1	1	0	8.696	0.444	2.347
2	1	1	-1	1	0	-6.533	0.444	-1.653
2	1	1	-1	1	0	-6.303	0.444	-1.653
1	1	1	-1	1	0	-6.083	1.444	-2.653
5	1	1	-1	1	0	-5.833	-0.556	-1.653
0	-1	1	-1	1	0	-5.333	1.444	-1.653
0	-1	1	-1	1	0	-5.083	-0.556	2.347
1	-1	1	-1	1	0	-4.813	1.444	-2.653
0	-1	1	-1	1	0	-4.583	-0.556	-0.653
2	-1	-1	-1	-1	-1	-4.083	-0.556	0.347
2	-1	-1	-1	-1	-1	-3.603	0.444	1.347
1	-1	-1	-1	-1	-1	-3.103	2.444	0.347
0	-1	-1	-1	-1	-1	-2.603	0.444	0.347
0	-1	-1	-1	-1	-1	-2.333	0.444	-2.653
0	-1	-1	-1	-1	-1	-2.083	1.444	1.347
0	-1	-1	-1	-1	-1	-1.833	1.444	-1.653
0	-1	-1	-1	-1	-1	-1.583	1.444	0.347
2	1	1	-1	-1	-1	2.686	-0.556	1.347
12	1	1	-1	-1	-1	3.186	-0.556	3.347
8	1	1	-1	-1	-1	3.686	0.444	0.347
8	1	1	-1	-1	-1	4.186	1.444	-0.653
5	1	1	-1	-1	-1	4.346	0.444	-3.653
3	1	1	-1	-1	-1	4.716	-0.556	0.347
12	1	1	-1	-1	-1	4.966	-0.556	0.347
6	1	1	-1	-1	-1	5.216	-0.556	3.347
2	1	-1	-1	1	0	5.416	1.444	0.347
0	1	-1	-1	1	0	5.686	0.444	0.347
0	1	-1	-1	1	0	5.916	-0.556	7.347
2	1	-1	-1	1	0	6.186	-0.556	-0.653
0	-1	-1	1	1	0	6.686	-0.556	6.347

- continued -

Appendix Table A-1. Number of male king crab, design matrix, and covariates (continued).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0	-1	-1	1	1	0	6.916	-0.556	5.347
0	-1	-1	1	1	0	7.186	0.444	0.347
0	-1	-1	1	1	0	7.416	-0.556	-2.653
6	1	1	1	1	0	-7.753	-0.556	-3.653
0	1	1	1	1	0	-7.483	-0.556	-3.653
0	1	1	1	1	0	-7.253	-0.556	-1.653
1	1	1	1	1	0	-6.983	-0.556	-3.653
0	-1	1	1	1	0	-6.453	0.444	-2.653
1	-1	1	1	1	0	-6.203	-0.556	0.347
0	-1	1	1	1	0	-5.953	-0.556	-2.653
0	-1	1	1	1	0	-5.703	-0.556	-2.653
2	-1	-1	0	0	1	-5.453	0.444	0.347
0	-1	-1	1	-1	-1	-5.203	-0.556	-2.653
1	-1	-1	0	0	1	-4.953	-0.556	1.347
2	-1	-1	1	-1	-1	-4.703	-0.556	-2.653
6	-1	-1	0	0	1	-4.453	-0.556	-1.653
0	-1	-1	1	-1	-1	-4.203	-0.556	1.347
4	-1	-1	0	0	1	-3.953	0.444	-1.653
2	-1	-1	1	-1	-1	-3.703	-0.556	1.347
0	-1	-1	1	-1	-1	-3.453	0.444	5.347
0	-1	-1	1	-1	-1	-3.203	-0.556	-1.653
0	-1	-1	1	-1	-1	-2.953	0.444	0.347
5	-1	-1	1	-1	-1	-2.703	-0.556	0.347
10	1	1	0	0	1	1.296	-0.556	1.347
2	1	1	1	-1	-1	1.546	-0.556	-0.653
9	1	1	0	0	1	1.796	0.444	-2.653
0	1	1	1	-1	-1	2.046	-0.556	-2.653
13	1	1	0	0	1	2.296	-0.556	-2.653
4	1	1	1	-1	-1	2.546	-0.556	1.347
14	1	1	0	0	1	2.796	0.444	-1.653
5	1	1	1	-1	-1	3.046	-0.556	-1.653
3	1	1	1	-1	-1	3.296	-0.556	1.347
0	1	1	1	-1	-1	3.546	-0.556	-0.653
1	1	1	1	-1	-1	3.796	-0.556	-1.653
3	1	1	1	-1	-1	4.046	-0.556	-1.653
0	1	-1	1	1	0	4.296	0.444	0.347
0	1	-1	1	1	0	4.546	-0.556	1.347
0	1	-1	1	1	0	4.796	-0.556	-0.653
0	1	-1	1	1	0	5.046	-0.556	-2.653

Appendix Table A-2. Latitude and longitude readings recorded for the sample station locations for the additional data collected at the south-west end of Kodiak Island.

Sample station location in each 4 by 4 block:

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16

Sample Location	Latitude Degrees	Latitude Min.	Longitude Degrees	Longitude Min.
Block 1				
1	57	0.43	155	3.30
2	57	0.43	155	2.87
3	57	0.43	155	2.45
4	57	0.45	155	1.99
5	57	0.18	155	3.30
6	57	0.18	155	2.87
7	57	0.18	155	2.45
8	57	0.18	155	1.99
9	56	59.93	155	3.30
10	56	59.93	155	2.87
11	56	59.93	155	2.45
12	56	59.93	155	1.99
13	56	59.68	155	3.30
14	56	59.68	155	2.87
15	56	59.68	155	2.45
16	56	59.68	155	1.99
Block 2				
1	56	59.00	155	5.00
2	56	59.00	155	4.56
3	56	59.00	155	4.14
4	56	59.00	155	3.68
5	56	58.75	155	5.00
6	56	58.75	155	4.56
7	56	58.75	155	4.14
8	56	58.75	155	3.68
9	56	58.50	155	5.00
10	56	58.50	155	4.56
11	56	58.50	155	4.14
12	56	58.50	155	3.68
13	56	58.25	155	5.00
14	56	58.25	155	4.56
15	56	58.25	155	4.14
16	56	58.25	155	3.68

Appendix B. Experimental design considerations.

The goal of experimental design is to partition the various sources of variability so that the true effects of the treatment of interest can be measured. There are many sources of variability that can obscure the results if the design does not accommodate for the additional effects. The major sources of variability in this study were considered at the planning stage so that the design of the experiment would be sufficient to provide meaningful information. The information was expected to be either conclusive, or sufficient to provide meaningful information for the design of another study. In many situations, an initial experimental design can only provide the necessary information for proper design of a subsequent study.

Confounding was a major problem and necessity in a study of this type in which time is the treatment and the constraints of the sampling mechanism interject an additional time problem. The initial analysis verified confounding with the existence of singularity, or non-full rank, of the design matrix when higher order interactions were included. Initial graphical analysis confirmed the problem of interpretation of confounded interaction effects. However, the interactions were viewed to be minor enough to assume no interactions, and thereby retain a degree of simplicity of presentation and interpretation. A multivariate approach (MANOVA) may provide a different interpretation. The assumption of parallelism of slope for the effect of covariates, or interactions between the covariates and factors, was assumed to be appropriate based on a cursory graphical review.

The use of indicator variables in the design matrix to identify the various treatment levels in the regression model provides the basis for testing the hypothesis of no treatment effect with the test statistic

$$F^{*} = \frac{SSE(R) - SSE(F)}{df(R) - df(F)} \div \frac{SSE(F)}{df(F)}$$

where SSE is the sum of squares of error, df is the appropriate error degrees of freedom, and (R) indicates the reduced model and (F) indicates the full model (Snedecor and Cochran 1967, Neter and Wasserman 1974). The test statistic is F-distributed with (df(R) - df(F), df(F)) degrees of freedom. The factors and covariates were tested sequentially with an extra-sums of squares approach based on the decision criteria of testing the effect of the variable (or set in the case of soak-time) with the smallest t-value or F-to-enter value. An effect was considered to be significant if the probability of a Type I error was less than or equal to 0.10 ($\alpha = 0.1$).

Appendix C. Chiniak Gully data - dependent variables, design matrix, and covariates.

The following is the data file utilized in the analysis. The column numbers correspond to the following variables:

1) Total numbers of crab
2) Number of male king crab
3) Number of female king crab
4) Number of male Tanner crab
5) Number of female Tanner crab
6 - 10) x_1 through x_5
11 - 13) z_1 through z_3

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
12	8	0	0	4	-1	-1	-1	1	0	7.074	1.25	2.014
14	4	1	0	9	-1	-1	-1	1	0	7.274	0.25	6.014
43	11	0	0	32	-1	-1	-1	1	0	7.514	-0.75	8.014
17	6	1	0	10	-1	-1	-1	1	0	7.794	-0.75	4.014
16	5	7	0	4	1	1	-1	1	0	-6.593	1.25	0.014
67	16	32	0	19	1	1	-1	1	0	-6.373	-0.75	0.014
23	13	4	0	6	1	1	-1	1	0	-6.153	0.25	-0.986
51	22	18	0	11	1	1	-1	1	0	-5.853	2.25	-1.986
6	5	0	0	1	-1	1	-1	1	0	-5.593	0.25	0.014
50	14	28	0	8	-1	1	-1	1	0	-5.403	-0.75	-1.986
18	7	3	1	7	-1	1	-1	1	0	-5.143	-0.75	-1.986
22	10	4	0	8	-1	1	-1	1	0	-4.823	0.25	0.014
57	16	7	0	34	-1	-1	-1	-1	-1	-4.343	-0.75	1.014
62	9	14	1	38	-1	-1	-1	-1	-1	-3.843	-0.75	1.014
42	11	11	0	20	-1	-1	-1	-1	-1	-3.343	-0.75	2.014
34	21	1	0	12	-1	-1	-1	-1	-1	-2.853	0.25	-0.986
43	25	4	1	13	-1	-1	-1	-1	-1	-2.573	-0.75	3.014
20	13	0	0	7	-1	-1	-1	-1	-1	-2.323	0.25	2.014
20	8	0	0	12	-1	-1	-1	-1	-1	-2.053	1.25	2.014
49	22	5	1	21	-1	-1	-1	-1	-1	-1.843	-0.75	-1.986
30	13	11	3	3	1	1	-1	-1	-1	2.657	-0.75	-0.986
33	12	9	2	10	1	1	-1	-1	-1	3.157	0.25	1.104
33	13	16	0	4	1	1	-1	-1	-1	3.657	0.25	3.014
58	16	15	0	27	1	1	-1	-1	-1	4.157	1.25	-0.986
48	9	15	1	23	1	1	-1	-1	-1	4.457	-0.75	0.014
78	13	19	0	46	1	1	-1	-1	-1	4.707	-0.75	-0.986
69	6	21	1	41	1	1	-1	-1	-1	4.897	0.25	-0.986
94	13	34	1	46	1	1	-1	-1	-1	5.157	-0.75	-0.986
5	1	1	0	3	1	-1	-1	1	0	5.397	0.25	0.014
34	7	22	0	5	1	-1	-1	1	0	5.697	-0.75	2.014
16	2	12	0	2	1	-1	-1	1	0	5.907	-0.75	2.014
4	4	0	0	0	1	-1	-1	1	0	6.157	1.25	1.014
5	4	0	0	1	-1	-1	1	1	0	6.427	0.25	1.014

- continued -

Appendix C (continued).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
8	3	3	0	2	-1	-1	1	1	0	6.677	-0.75	4.014
13	3	0	0	10	-1	-1	1	1	0	6.927	-0.75	0.014
13	8	1	0	4	-1	-1	1	1	0	7.157	0.25	-0.986
34	10	17	0	7	1	1	1	1	0	-7.356	-0.75	-0.986
37	11	18	0	8	1	1	1	1	0	-7.126	-0.75	-0.986
41	9	23	0	9	1	1	1	1	0	-6.876	-0.75	-0.986
44	14	29	0	1	1	1	1	1	0	-6.606	-0.75	-1.986
25	14	4	0	7	-1	1	1	1	0	-6.356	0.25	-2.986
31	17	12	0	2	-1	1	1	1	0	-6.126	-0.75	-1.986
17	12	4	0	1	-1	1	1	1	0	-5.876	-0.75	-1.986
11	9	0	0	2	-1	1	1	1	0	-5.606	1.25	-1.986
56	13	1	0	42	-1	-1	0	0	1	-5.356	0.25	-1.986
25	10	0	0	15	-1	-1	1	-1	-1	-5.126	1.25	-2.986
95	6	0	2	87	-1	-1	0	0	1	-4.856	-0.75	-2.986
42	6	20	0	16	-1	-1	1	-1	-1	-4.624	-0.75	-0.986
72	11	6	1	54	-1	-1	0	0	1	-4.376	0.25	-0.986
45	15	17	0	13	-1	-1	1	-1	-1	-4.126	-0.75	1.014
49	16	1	2	30	-1	-1	0	0	1	-3.876	-0.75	-1.986
35	16	8	0	11	-1	-1	1	-1	-1	-3.626	-0.75	1.014
6	6	0	0	0	-1	-1	1	-1	-1	-3.386	0.25	-0.986
26	20	1	0	5	-1	-1	1	-1	-1	-3.136	-0.75	-0.986
10	6	0	0	4	-1	-1	1	-1	-1	-2.856	1.25	2.014
17	6	8	1	2	-1	-1	1	-1	-1	-2.606	0.25	-0.986
73	14	1	3	55	1	1	0	0	1	1.624	1.25	-1.986
21	13	8	0	0	1	1	1	-1	-1	1.874	-0.75	-1.986
60	10	8	1	41	1	1	0	0	1	2.124	0.25	0.014
19	5	14	0	0	1	1	1	-1	-1	2.374	0.25	-1.986
43	11	8	2	22	1	1	0	0	1	2.624	1.25	-1.986
5	4	1	0	0	1	1	1	-1	-1	2.864	2.25	1.014
35	9	6	1	19	1	1	0	0	1	3.144	1.25	-0.986
10	4	5	0	1	1	1	1	-1	-1	3.374	0.25	0.014
36	10	20	0	6	1	1	1	-1	-1	3.664	1.25	1.014
31	5	4	0	22	1	1	1	-1	-1	3.914	-0.75	-1.986
28	7	7	0	14	1	1	1	-1	-1	4.144	-0.75	1.014
13	0	4	0	9	1	1	1	-1	-1	4.374	1.25	-1.986
12	2	5	0	5	1	-1	1	1	0	4.624	-0.75	2.014
3	3	0	0	0	1	-1	1	1	0	4.874	-0.75	-0.986
4	1	3	0	0	1	-1	1	1	0	5.164	-0.75	5.014
5	1	4	0	0	1	-1	1	1	0	5.394	1.25	-0.986